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HANDBOOK  
FOR  
WATER-DRINKERS  
—  
AUSTIN

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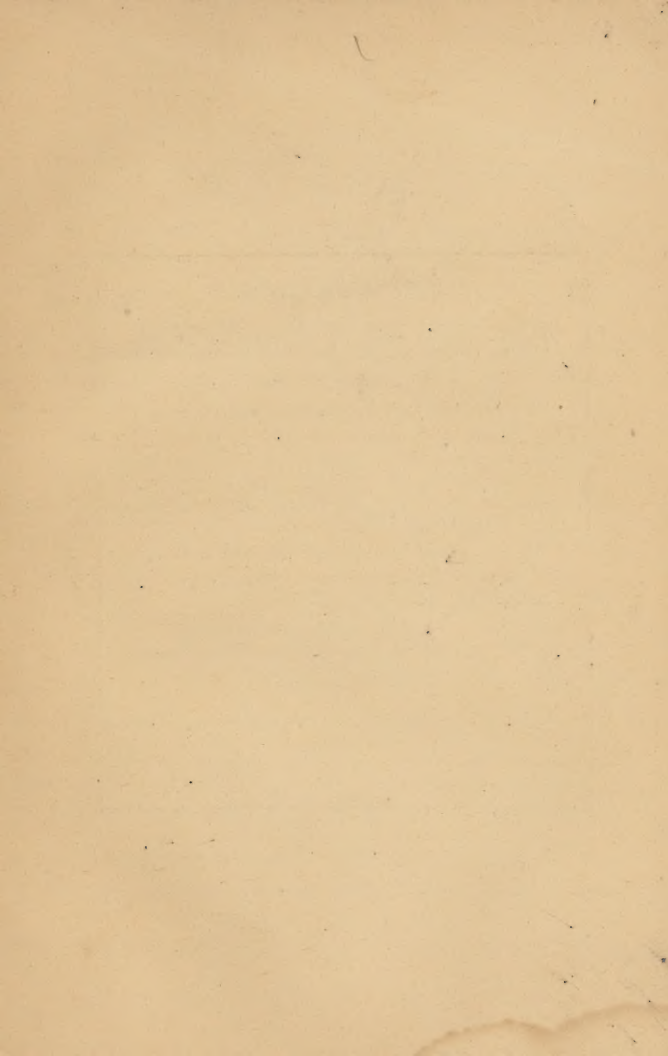
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# WATER-ANALYSIS

*A HANDBOOK*

FOR WATER-DRINKERS

BY

G. L. AUSTIN, M.D.

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## PREFACE.

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IN the preparation of this little volume, I have had in view the single object of placing in the hands of persons, who are not professional or expert chemists, a ready and pleasing method of determining water-analysis to the extent necessary to afford a perfect idea as regards its wholesomeness or unwholesomeness for drinking purposes. I venture to hope that the work may prove of some service in this direction.

G. L. A.

BOSTON, August, 1882.



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## WEIGHTS AND MEASURES.

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CHEMISTS of all countries employ the French or Metric System of measurement, — the litre, the cubic centimetre, and the gramme being the three units of most frequent occurrence in chemical works. The following data will assist the student of water-analysis : —

1 litre = 2.113 pints or 15,434 grains.

1 cubic centimetre = 0.001 of a litre.

1 gramme = the weight of 1 cubic centimetre of water at the freezing temperature.

1 gramme = weight of 1 cubic centimetre water at 39° F., written . . . . . 1.

1 decigramme =  $\frac{1}{10}$  of a gram, written . . . .1

1 centigramme =  $\frac{1}{100}$  of a gram, written . . . .01

1 milligramme =  $\frac{1}{1000}$  of a gram, written . . . .001

# WATER-ANALYSIS.

## *HANDBOOK FOR WATER-DRINKERS.*



### INTRODUCTORY REMARKS.

THERE is no doubt that perfect health, whether in the individual or in the community, depends largely upon the purity of the water used for drinking or for domestic purposes. We find people triumphantly asserting that they have been endangering their health during a great many years, and are not, to their own knowledge, at all the worse for the filth that they have taken with their water. They conclude, therefore, that impure water, like strong tea, which the old woman of ninety was informed was a stealthy poison, must be exceedingly slow in its action. There is truth, as well as the contrary, in this assertion. What is one man's poison may prove

harmless to another man ; and the susceptibility to disease is not the same in all individuals. It is possible for a physician to demonstrate that a certain water has caused a fatal diarrhœa in one or more persons, but has had no effect whatever on other persons that have used the water as freely.

Again, there is no doubt that much of the mortality in large cities and towns is occasioned by the habitual use of pond-water, or river-water that has been stored in immense reservoirs. Certain facts about such waters are known, viz. : that pond-water, as commonly met with, is very apt to originate diarrhœa in summer ; to give rise to intestinal worms ; and to favor, if indeed not to produce, the prevalence of malarial diseases. If the pond-water chances to become fouled by the excreta of cattle, a sort of continued fever will be likely to affect the persons drinking the water. Human offal draining into the pond will give rise to even more serious consequences.

The danger which threatens the denizens of

large cities from the use of impure pond or river water also threatens country people from the use of water taken from shallow or surface wells. Such water is apt to become contaminated with sewage-matter; and although we have strong grounds for the belief that typhoid-fever is propagated as the other fevers, such as scarlatina, small-pox, etc., by the special poison of each finding its way from the bodies of infected persons to those who are in a state of health, but in whom, from certain predisposing causes, the conditions necessary for the germination and reproduction of the specific poison exist,—or, in other words, that specific fevers are not generated by the decomposition of animal matter, unless the specific poison which has been generated in the body of an infected person is present in such matter,—still we know that there is soakage from ash-pits, dumb-wells, and cesspools, throughout the country, to an enormous and frightful extent; and it will readily be conceived that water thus laden with animal matters in a state of decomposition must pro-



duce a lowered, if not putrescent, state of the whole system in those who drink it, and thus render them infinitely more liable to succumb to the poison of any kind of fever on exposure to it. Hence it is most important that the sources of water-supply should be carefully examined.

The importance of the purity of drinking-water cannot be too strongly urged or insisted upon. When there is any reason for suspecting the purity of a water, it should at once be tested, so as to settle the question. Such work is left altogether too much to local boards of health throughout the country; and herein lies a mistake. Every physician ought to know how to make an analysis of every sample of water, the healthfulness of which he suspects; nay, more, every householder ought at least to understand the simpler tests.

The following pages are intended to throw some light on this subject, as well as to furnish details of the methods of analyzing waters for sanitary purposes. The proceeding from first

to last is not difficult : on the contrary, it is both easy and interesting.

The increased demand for spring-waters at the present time, particularly in large cities, plainly shows that people are becoming sensible, and are awakening to the belief that in impurity lurk disease and death. A perfectly pure spring-water is certainly the most healthful beverage in the world : such waters are abundant, and can now be easily obtained. It will be a happy day for us all when their use shall have become general or universal for drinking purposes.

#### OBJECTS OF WATER-ANALYSIS.

OF all waters used for drinking purposes, undoubtedly a pure spring-water, entirely devoid of mineral substances, is the most wholesome. A pure shallow well water occupies the next place ; the water furnished by an artesian well, and the rain that descends in the country far away from large cities and towns, hold jointly a third position in order of merit ; and lastly come the waters supplied by rivers, ponds, and

lakes, the vast majority of which are contaminated by more or less filth, and in times of heavy rains contain soil and mineral *débris* of every description.

Notwithstanding the above classification, which is by no means arbitrary, it is almost impossible to define a wholesome water. It is certain, however, that, in forming an opinion in regard to the wholesomeness or unwholesomeness of a drinking-water, certain particulars should be previously ascertained, namely : —

1. The amount and nature of the organic matter which is contained in the water.
2. The existence, or not, of the products of the oxidation of organic matter ; such as the nitrates and nitrites, and in certain cases the quality of these salts.
3. The amount and nature of the saline constituents.
4. The degree of hardness.
5. The existence, and the amount if present, of metals.
6. The existence and the amount of purga-

tive salts ; such as the sulphate and carbonate of magnesia, or the sulphates of soda and potash.

In the majority of cases where the effect of the water on health is concerned, information on the first two points above named is alone needed.

For most sanitary purposes, then, a water-analysis is complete when it includes these data, —

Total solids, chlorine, “free and albuminoid ammonia,” poisonous metals.

When undertaking to analyze a sample of water, from whatever source, it should be remembered that the question which requires an answer is, “Is this water wholesome and good?” The response is half rendered by learning what reason there is for complaining of the water. Has it caused any illness in the family? Is the taste nauseating, or the odor offensive? Having satisfied one’s self on these points, the next step is to proceed with the analysis.

The sample taken should be at least a half-gallon, and this should be contained in a glass-stoppered bottle. A clean cork may answer, provided it is clean. When drawing water from a street-main, it is a wise precaution to allow a little water to run away, so as to clear the pipe before collecting the sample.

The sample of water is now in hand ; and an opportunity is afforded to note the coarser physical properties or characters, such as color, odor, taste, and transparency.

The COLOR is best observed by pouring some of the water in a tall glass vessel, and looking down upon it. If the water has a bluish tint, and the bottom of the vessel is distinctly seen, there is at least one good reason for supposing that the water is pure. As a rule, a green color in the water denotes vegetable impurity, while a yellow or brown color (excepting in peat water) indicates animal impurity. If the sample of water is taken from a river or pond, this test is almost infallible.

The simplest way to detect the SMELL of a

water is to partly fill a clean bottle with a sample of it, and, having violently shaken the same, to take a hearty sniff at the air of the bottle which has been agitated with the water. If the air smells fresh and sweet, the absence of an injurious amount of organic matter is to be inferred, and *vice versa*.

Any peculiarity in the TASTE of a water is easily noticed. Waters, the odor of which is offensive, are also unpalatable on account of the excess of chlorides and other saline matters which they contain. These are popularly denominated as "brackish" waters. Other waters from the clay have a decided odor of sulphuretted hydrogen gas, and become turbid on standing, in consequence of the separation of sulphur: such are the "rotten-egg" waters, so called. The waters of many ponds and rivers in this country possess a peculiar fish-like odor and taste. This is due to some obscure condition of certain undetermined species of algæ, also of some species that have been determined, and probably to their decay and decomposition. There is no longer

any doubt in the minds of the most competent judges, that the drinking of such water for any duration of time is exceedingly deleterious to health.

As a rule, the perfect TRANSPARENCY of a water, especially when it is of a bluish cast, is a strong indication of its purity, or freedom from organic matter.

While the evidence afforded by an examination of the coarser physical characters of a water is tolerably reliable in many instances, still, in by far the majority of cases, it cannot be depended upon. The true facts of the case must be sought by an examination of the dissolved solids. The examination is divided into the qualitative and quantitative.

#### APPARATUS AND RE-AGENTS.

A purely sanitary examination of a water does not call for expensive apparatus or a large number of chemicals. The following apparatus will answer most purposes: one small flask, with ring for boiling; pipette, graduated to one-tenth

cubic centimetre ; one retort-stand ; one burette with clamp ; india-rubber tubing ; one small spirit-lamp ; six test-tubes ; one glass rod ; one glass measure, graduated to one hundred cubic centimetres.

The following chemicals, in two-ounce bottles, will be needed : standard solution of nitrate of silver, solution of soap, Nessler's solution, hydrochloric acid, standard solution of weak ammonia, standard solution of permanganate of potassium, Wanklyn's solution, yellow chromate of potash, sulphuret of ammonium ; solutions of lead, copper, and iron ; oxalate of ammonium.

The formulæ for making the solutions will be found in the Appendix. Most persons of ordinary ingenuity or skill can easily prepare them ; or, if this be not convenient, any druggist will carefully compound them on order.

We now proceed with the analysis.

### I.—QUALITATIVE.

**LIME.**—The presence of this salt in a given sample of water is easily detected by the follow-



ing proceeding : Pour one litre of the water into a clean bottle, and add slowly one gramme of the powdered oxalate of ammonium ; after shaking the mixture for a few moments, filter. The residue will be in the shape of a white powder, oxalate of lime.

MAGNESIA. — After the foregoing proceeding, again add a little oxalate of ammonium to the filtrate, and pass through a clean filter. Then take seventy cubic centimetres of the filtrate and triturate with a little of the soap solution, and let stand for a while. If there be any degree of hardness remaining in the water, it will indicate the presence of magnesia.

CHLORINE. — The presence of chlorine in drinking-water is in itself a matter of very little importance, unless we also know whether or not the water also contains an amount of organic matter. In an indirect manner, however, the presence of chlorine, especially when excessive, is indicative of sewage or of urine. Hence it occasionally happens that the finding of little or no chlorine in a sample of water is a valuable

test of purity. When the water is found to contain much chlorine, there is reason for suspecting the contamination of urine or sewage, especially if the source of the water be a well situated near a privy or cesspool. To determine the presence of chlorine, proceed as follows: Take a small sample of the water, and add slowly a few drops of the standard solution of nitrate of silver; if chlorine be present, a white precipitate of chloride of silver will continue to form, and settle to the bottom of the vessel.

AMMONIA. — This salt, which is itself harmless, is a product of the decomposition of animal organic matter, and is present in air in exceedingly variable quantity, out of which it is washed by the great air-cleanser, — rain. Rain contains about .49 part per million of ammonia. River-water rarely contains more than .1 part per million of ammonia. Unpolluted well-water contains even less, while spring-water is almost free from ammonia.

Inasmuch as ammonia, in contact with animal

matter, and subject to oxidizing influences, is rapidly converted into nitrates and nitrites, its presence in excessive quantity in small streams and shallow wells indicates their very recent and direct pollution with animal matters. The excess is invariably accompanied by an excess of what is called "albuminoid ammonia." In the case of wells, the contamination is probably by urine.

To detect the presence of ammonia in a given sample of water, add to it a small quantity of Nessler's solution: a yellow color, or yellow-brown precipitate, shows the presence of ammonia. The examination is most conveniently performed by using a test-tube.

ORGANIC MATTER.—The foregoing determinations are only of secondary importance in comparison with the detection of organic matter in drinking-water; and it is to the latter that the water-analyst should chiefly direct his attention. All waters, even the purest, contain some organic matter. It is the excess which is alone objected to, and especially when it is of animal

origin, which is so prone to pass through certain putrefactive changes.

The readiest method of testing for organic matter in water is to add two or three drops of the standard solution of permanganate of potassium to the water to be examined in a test-tube, and to note the extent to which the original pinkish tint is replaced by a brown color, and the rapidity of the change. While this test is by no means satisfactory in its results, it is still the best that is known at present for quick determinations. The method employed for the quantitative examination for organic matter, to be explained later on, is of course very accurate; and in its earlier stage will serve for a qualitative examination.

## II.—QUANTITATIVE.

ORGANIC MATTER. — To determine the amount of organic matter that may be present in a given sample of drinking-water, what is known to chemists as the “Wanklyn process” yields the best results. The principle of the method is measurement of the nitrogenous organic

matter in waters by the quantities of ammonia yielded by the destruction of the organic matter. For the measurement of the quantities of ammonia, the very delicate Nessler test is utilized ; the agents for the destruction of the organic matter are permanganate of potassium, a large excess of caustic potash, and boiling the solution. The following is the process : —

Select a glass retort which holds rather more than a litre when it is quite full, and which is tubulated and properly stoppered, and first wash it out with a little strong sulphuric acid, and afterwards thoroughly with good tap-water, until every trace of acidity is removed. Then mount it in a holder, and properly connect it with a Liebig condenser by means of a wide india-rubber tube. Through a large funnel pour half a litre of the sample of water to be tested into the retort ; insert the stopper, and, having lighted the Bunsen lamp,<sup>1</sup> allow the flame to come in contact externally to the naked retort

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<sup>1</sup> A good size spirit-lamp will answer, but the Bunsen burner and gas afford speedier results.

on a level with the water that is within it. In a few minutes the water will begin to boil, and to distil over. The distillate is to be collected in the glass cylinders for the Nessler test.

When fifty cubic centimetres of the distillate have passed, the cylinder is to be changed. The distillation is to be continued until one hundred and fifty cubic centimetres have come over, and the one hundred and fifty cubic centimetres of distillate are to be thrown away. Having done so, and thereby reduced the contents of the retort from five hundred cubic centimetres — the quantity originally taken — to three hundred cubic centimetres, the distillation is stopped for a moment.

Now pour fifty cubic centimetres of Wanklyn's solution into the retort, and again proceed with the distillation. Shake the retort occasionally to prevent bumping. Continue the distillation until fifty cubic centimetres of distillate have come over, which set aside for the Nessler test. A second fifty cubic centimetres must be collected in another cylinder, also a third fifty

cubic centimetres. Then stop the distillation, and allow the apparatus to stand until it is required for another analysis.

Now begin to "Nesslerize ;" that is, by means of the Nessler test, determine the strength of the dilute solutions of ammonia. It should be borne in mind, of course, that ammonia is to be looked for at two stages of the water-analysis : firstly, before the addition of the Wanklyn solution ; and, secondly, after its addition. In the first stage the ammonia which comes over is the "free ammonia," and that which comes over in the second stage is the "albuminoid ammonia."

Add to the first distillate of fifty cubic centimetres, containing the free ammonia, by means of a bulb pipette, two cubic centimetres of the Nessler solution. If it contains ammonia, a yellowish-brown or amber color is produced ; the deeper the color the more ammonia being contained in it. A pale straw tint will indicate a very small amount of ammonia.

The next step is to imitate the depth of color

given by the distillate. Take a clean cylinder, and into it drop a certain measured volume of the standard solution of weak ammonia, which is filled up with distilled water to the fifty cubic centimetres' mark on the cylinder. Two cubic centimetres of the Nessler solution is then dropped into it by means of the pipette, and the whole is very thoroughly stirred up. The fifty cubic centimetres of distillate in its appropriate cylinder, and the fifty cubic centimetres of water containing the standard ammonia, are then placed side by side on a white surface, and carefully looked through. If they be of equal depth of color, the Nesslerizing is accomplished ; if they be unequal, another standard must be made up with water, dilute standard ammonia, and Nessler solution, and another comparison be made. The first fifty cubic centimetres of the distillate invariably contains three-quarters of the total amount of free ammonia. The rule is, therefore, to Nesslerize the first fifty cubic centimetres of free ammonia, and then to add one-third : thus, if the first fifty centimetres of



distillate contain .02 milligramme of free ammonia, the total free ammonia would be .027 milligramme.

In the instance of the albuminoid ammonia, it is necessary to Nesslerize each separate fifty cubic centimetres of distillate, and to add the amounts together, in order to arrive at the total albuminoid ammonia. For example, if the amount of dilute standard solution of ammonia required to match the tint of the first distillate be five cubic centimetres, second distillate be three cubic centimetres, third distillate be one cubic centimetre, we arrive at these figures : —

|                              |     |
|------------------------------|-----|
| Albuminoid ammonia . . . . . | .05 |
|                              | .03 |
|                              | .01 |
|                              | —   |
| Total . . . . .              | .09 |

Since half a litre of water is taken for the analysis, the results must be multiplied by two, in order to make them count upon the litre ; and, if that be done, we shall then have the “free ammonia” and the “albuminoid ammonia” ex-

pressed in milligrammes per litre, or in parts per million, which is the same thing.

The following rule is laid down by Mr. Wanklyn, for the guidance of those who work this process: "If a water yield .00 parts of albuminoid ammonia per million, it may be passed as organically good and pure, despite of much free ammonia and chlorides; and if, indeed, the albuminoid ammonia amounts to .02, or to less than .05 parts per million, the water belongs to the class of very pure water. When the albuminoid ammonia amounts to .05, then the proportion of free ammonia becomes an element in the calculation; and I should be inclined to regard with some suspicion a water yielding a considerable quantity of free ammonia, along with more than .05 parts of albuminoid ammonia per million. Albuminoid ammonia above .10 per million begins to be a very suspicious sign, and over .15 ought to condemn a water absolutely."

CHLORINE. — To determine the amount of chlorine in a water, proceed as follows: Place

seventy cubic centimetres of the water to be examined in a porcelain dish, and add a minute morsel of pure chromate of potash to make it just yellow. Then, by means of a pipette graduated to one-tenth of a cubic centimetre, and filled with five cubic centimetres of the solution of nitrate of silver, this standard solution should be allowed to drop into the water until the red color produced ceases to disappear. As soon as the red tint becomes permanent, note the amount of silver solution necessary to reach this point. Run a little more silver solution into the water, to be sure that the water is not acid; for chromate of silver is soluble in acids. The number of cubic centimetres of the silver solution employed will represent the number of grains of chlorine per gallon.

HARDNESS. — This is estimated by the soap-test, and by it we determine, —

1st, The total hardness, representing the aggregate earthy salts and free carbonic acid.

2d, The removable hardness, or that which disappears on boiling.

3d, The permanent hardness, which is unaffected by boiling.

By the soap-test can also be determined the amount of certain constituents, such as lime, magnesia, sulphuric acid, and free carbonic acid.

*To determine the Total Hardness of the Water.*

—Place seventy cubic centimetres of the water to be examined in a stoppered bottle holding about two hundred and fifty cubic centimetres. The standard soap solution is dropped slowly, by means of a pipette graduated to one-tenth of a cubic centimetre, into the bottle, which is frequently shaken violently, to note the amount of soap solution necessary to create a persistent lather. After each shaking, remove the stopper of the bottle for a few moments, to allow the escape of the carbonic acid gas which is evolved.

If the water is so hard that the addition of sixteen cubic centimetres of soap solution does not produce a lather, add seventy cubic centimetres of distilled water, and mix. Then continue the addition of the soap solution. If the dropping of soap solution be proceeded with

until a second sixteen cubic centimetres be consumed without the formation of a permanent lather, a second seventy cubic centimetres of distilled water must be added.

|                                                                                           |    |
|-------------------------------------------------------------------------------------------|----|
| Suppose, for example, nineteen cubic centimetres of                                       |    |
| soap solution are necessary . . . .                                                       | 19 |
| Deduct for hardness of each seventy cubic centimetres of distilled water employed . . . . | 1  |
| Degrees of hardness . . . . .                                                             | 18 |

To know the quantity of carbonate of lime, or other hardening and soap-destroying ingredients contained in the water, subtract one degree. Thus in the case just cited, the water contains seventeen grains or carbonate of lime, or salts equivalent, per gallon.<sup>1</sup>

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<sup>1</sup> A gallon of water is an unwieldy quantity to work with: hence we employ, in practice, a much smaller volume, and a correspondingly small fraction of the quantity of soap in the measure of standard soap solution. We take a miniature gallon, —viz., seventy cubic centimetres of water, —which contains as many milligrammes of water as there are grains in a gallon. The standard soap solution is made to contain exactly sufficient soap in one cubic centimetre to precipitate one milligramme of carbonate of lime. When, therefore, the miniature

*To determine the Permanent Hardness.* — Boil a sample of the water for about half an hour, and when cold replace what is lost as steam with distilled water. Allow any floating particles that may be present to subside, and then examine it with the soap-test as before. The result will show the degrees of permanent hardness.

*The Removable or Temporary Hardness* will be the difference between the total and the permanent hardness.

The degree of hardness is a matter to be considered in pronouncing on the wholesomeness of a water. The permanent hardness of good water should not exceed three or four degrees. In the calculation, the permanent hardness is the most important, for it represents the most objectionable earthy salts, viz.: cal-

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gallon and a certain number of cubic centimetres of standard soap solution are used, it is as if we had taken an actual gallon of water, and tested it with a certain number of measures of standard soap solution, whereof each measure contained soap equivalent to one grain of carbonate of lime,

cium, sulphate and chloride, and the magnesian salts, which in many persons cause dyspepsia, diarrhoea, etc.

#### TOTAL SOLIDS.

Ordinarily a porcelain dish will answer as well as a platinum dish, which is more expensive.

Take a dish capable of holding one hundred cubic centimetres, and, after cleansing it, weigh it carefully. Then put seventy cubic centimetres of the sample of water into the dish, and evaporate to dryness over a slow heat. After the evaporation is completed, again weigh the dish. The difference between the weighing will show the amount of total solids, — each milligramme representing one grain per gallon of water.

#### POISONOUS METALS IN WATER.

It sometimes happens that water used for domestic purposes, especially when taken from a shallow well, becomes contaminated by the presence of a metal of poisonous nature. For

testing, standard solutions of lead, copper, iron, etc., are required. Of these the formulæ will be found in the Appendix.

TO TEST FOR IRON.—Into seventy cubic centimetres of the sample of water contained in a dish of porcelain, a glass rod, which has been dipped into sulphuret of ammonium, is to be inserted, and the water is to be well stirred up. If iron be present, the liquid will assume a dark color; and the amount of iron may be determined by imitating the color, by means of the standard solution of iron. The manner of operation will be evident to all persons who have become familiar with the process of measuring ammonia by the Nessler test.

TO TEST FOR LEAD OR COPPER.—Take seventy cubic centimetres of the water as before. Stir it with a glass rod dipped in sulphuret of ammonia, and add a very little hydrochloric acid to render it faintly acid. Observe the color. This having been done, take seventy cubic centimetres of distilled water, into which a certain measured quantity of standard lead solution or



standard copper solution has been put, and similarly treat it with a drop of sulphuret of ammonium. Compare the resulting depth of color with that given by the sample of water.

Good drinking-water ought not to contain more than one-tenth or two-tenths grains of iron per gallon, and should contain less than one-tenth grain of lead or copper. It is unnecessary to determine whether the metal be lead or copper, for the presence of either would condemn the water for potable purposes.

Practically, the testing of water for metals resolves itself into the following simple procedure: Take seventy cubic centimetres of the sample, add a drop of sulphuret of ammonium, and stir with a glass rod: if there be any coloration, it should only be just visible; and, on adding two or three drops of hydrochloric acid, it ought to vanish absolutely. Water which answers to this test may be safely considered as free from poisonous metals; and the contrary result is indicative of metallic contamination, and should never be used for drinking purposes.

As a rule, metallic contamination forms the most fatal of all objections to drinking-water, and is far more difficult to remedy than organic contamination, which may usually be got rid of by proper filtration.

#### A PLAN FOR RAPID WATER-ANALYSIS.

Many persons may not have the inclination or the opportunity to carry out an analysis such as has been previously described. For their benefit the following ready tests are here given : —

1. Observe the color.
2. Observe the smell, particularly when the water is boiling.
3. Observe the taste.
4. Add to a small quantity of the water, in a test-tube, a little of the standard solution of nitrate of silver. If it gives a white color, the water contains chlorides. This is a suspicious sign.
5. To another sample of the water, add a small quantity of Nessler solution. A yellow

color, or yellow-brown precipitate, indicates the presence of ammonia.

6. To a small sample of the water, add a few drops of the solution of permanganate of potassium. The pink color lingers if the water is pure : it disappears if the water contains organic matter. But this test is not infallible.

In a great number of cases these simple tests will settle the question of the purity or impurity of a suspected water.

#### MICROSCOPIC EXAMINATION OF THE SEDIMENT OF A WATER.

Where there is any doubt as to the healthful quality of a drinking-water, a microscopic examination of the floating particles sometimes seen in it will often afford valuable information. Inorganic particles, such as silt of clay and sand, may be the cause of persistent diarrhoea, baffling the efficacy of medicines. The existence of animal life in a water affords good evidence in itself of the presence of a sensible amount of organic matter or filth ; for these

little creatures could not subsist in a perfectly pure water. It is highly probable that the poisons of several of the zymotic diseases find a congenial soil amid such organisms, which act as carriers, to which they attach themselves, and amongst which they multiply.

A perfectly pure water contains no suspended matter, nor any animal or vegetable life. Any good treatise on the use of the microscope, and especially Dr. Macdonald's "Guide to the Microscopical Examination of Drinking-Water," will prove helpful to all students of this branch of water-analysis.

#### THE MINIMUM OF SAFETY IN DRINKING-WATERS.

The constituent parts of water when pure are, in volumes, two parts of hydrogen and one part of oxygen, and, by weight, one part of hydrogen and eight parts of oxygen. When pure, water is also transparent, odorless, tasteless, and colorless, except when seen in considerable depths. Now, while it appears to be an established fact, that chemically pure waters are not

best for drinking-purposes, still there is a limit in the condition of impurity beyond which it is not safe to imbibe. Rain-water is almost always affected by atmospheric influences ; spring and well water very often become charged with mineral properties ; and, finally, the waters of rivers, lakes, and ponds, as a rule, contain more or less vegetable and animal organisms. But what is the minimum of safety ? Dr. Frankland of England furnishes the following conclusions as to what must be considered polluted water : —

1. Every liquid that contains in suspension more than one part, by weight, of dry organic matter in a hundred thousand parts of the liquid, or one part, by weight, of dry mineral matter in a hundred thousand parts of the liquid.

2. Every liquid containing in solution more than two parts, by weight, of organic carbon, or three parts of organic nitrogen, in a hundred thousand parts of the liquid.

3. Every liquid, which, when placed in a porcelain dish to the depth of one inch, exhibits under daylight distinct color.

4. Every liquid which contains in solution more than two parts, by weight, of any metal, except lime, magnesia, potash, and soda, in a hundred thousand parts of the liquid.

5. Every liquid which contains in solution or in suspension more than five-tenths part metallic arsenic, by weight, in every hundred thousand parts.

6. Every liquid, which, after the addition of sulphuric acid, contains more than one part, by weight, of free chlorine in every hundred thousand parts.

7. Every liquid which contains, by weight, more than one part of sulphur, in the state of sulphuretted hydrogen or of a soluble sulphuret, in every hundred thousand parts.

8. Every liquid possessing an acidity greater than that produced by adding two parts, by weight, of hydrochloric acid to one thousand parts of distilled water.

9. Every liquid possessing an alkalinity greater than that produced by adding one part, by weight, of caustic soda to one thousand parts of distilled water.

10. Every liquid exhibiting on its surface any film of petroleum or containing in suspension more than five-tenths part, by weight, of such oil in every one hundred thousand parts.

As has already been explained in these pages, it is most important that we should seek to avoid all waters tainted by organic matter, especially sewage. The presence of ammonia in any water offers valuable evidence of such contamination; since it is the measure of that portion of organic matter not decomposed, but in a state of or capable of undergoing putrefaction. More than five-tenths of a grain of free ammonia per one thousand gallons of water, or more than nine-tenths of a grain of albuminoid ammonia per one thousand gallons of water, forbodes danger to persons drinking the liquid.

It will be seen then, that, in many localities of this country, the public health is greatly and seriously endangered by the use of waters which are known to contain a very large percentage of organic matter. Nay, more, it is well known that in these communities those diseases which

are much dependent upon this kind of poison are very prevalent, and that the ratio of death-rate is excessive.

The following analyses, made by competent chemists, are something alarming. They exhibit the number of grains of sewage in each one thousand gallons of water : —

| CITY.         | Source.         | Date. | Grains<br>Free<br>Ammono-<br>nia. | Grains<br>Album.<br>Ammono-<br>nia. | Remarks.      |
|---------------|-----------------|-------|-----------------------------------|-------------------------------------|---------------|
| Philadelphia, | Schuylkill . .  | 1874  | 1.17                              | 1.76                                | Fairmount.    |
| Philadelphia, | Schuylkill . .  | 1874  | 5.85                              | 5.11                                | Belmont.      |
| Philadelphia, | Schuylkill . .  | 1874  | 7.31                              | 5.12                                | Flat Rock.    |
| Philadelphia, | Schuylkill . .  | 1874  | 1.46                              | 7.31                                | Perkiomen.    |
| Philadelphia, | Schuylkill . .  | 1874  | 17.50                             | 8.75                                | Spr'g Garden. |
| Philadelphia, | Delaware . .    | 1874  | 25.74                             | 11.70                               |               |
| London . .    | Artesian well,  | 1874  | -                                 | 1.75                                | Bryn Maws.    |
| London . .    | Thames . .      | 1874  | 1.00                              | 5.31                                |               |
| Detroit . .   | Detroit . .     | 1879  | 3.09                              | 7.29                                | Hydrant.      |
| Hoboken . .   | Passaic . .     | 1880  | 1.72                              | 19.22                               | Hydr't water. |
| Jersey City . | Passaic . .     | 1880  | 2.96                              | 22.28                               | Hydr't water. |
| Paterson . .  | Passaic . .     | 1880  | 1.50                              | 30.90                               | Hydr't water. |
| New York . .  | Croton . .      | 1880  | 1.00                              | 15.70                               | Hydr't water. |
| Brooklyn . .  | Long Island .   | 1880  | .50                               | 4.80                                | Hydr't water. |
| Boston . .    | Cochituate .    | 1880  | 7.60                              | 35.60                               | Hydr't water. |
| Rochester . . | Hemlock L. .    | 1880  | .90                               | 13.00                               | Hydr't water. |
| Philadelphia, | Schuylkill . .  | 1880  | .60                               | 10.50                               | Hydr't water. |
| Wilmington.   | Delaware . .    | 1880  | 2.00                              | 17.50                               | Hydr't water. |
| Baltimore . . | Jones's Falls . | 1880  | 2.90                              | 11.70                               | Hydr't water. |
| Washington,   | Potomac . .     | 1880  | 3.50                              | 15.70                               | Hydr't water. |
| Oswego . .    | . . . . .       | 1880  | 2.00                              | 15.20                               | Hydr't water. |
| Oswego . .    | Well . . . .    | 1880  | 4.90                              | 12.30                               |               |
| Cincinnati .  | Ohio River .    | 1880  | 6.70                              | 14.00                               | Hydr't water. |
| Chicago. .    | L. Michigan .   | 1881  | 2.84                              | 21.27                               | Hydr't water. |



In connection with the above table, the following tabulations from the Rivers Pollution Commission Report, 1874, should be examined, as showing the evil effects of impure water on health :—

## LONDON, ENG.

| YEAR. | Character of the Water.      | Mortality. | Rate per<br>10,000. |
|-------|------------------------------|------------|---------------------|
| 1832  | Polluted . . . . .           | 5,275      | 31.4                |
| 1849  | Very much polluted . . . . . | 14,137     | 61.8                |
| 1854  | Less polluted . . . . .      | 10,738     | 42.9                |
| 1866  | Much less polluted . . . . . | 5,596      | 18.4                |

## APPENDIX.

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THE following are the formulæ for making the several solutions called for in this book. Unless a person possesses all the chemicals in a pure state, it is best to have the solutions prepared by some competent druggist.

### STANDARD SOLUTION OF NITRATE OF SILVER.

Dissolve 4.79 grammes of crystallized nitrate of silver in one litre of distilled water. This solution is then of such a strength that one cubic centimetre of it is capable of precipitating exactly one milligramme of chlorine.

### NESSLER SOLUTION.

Dissolve by heating and stirring thirty-five grammes of iodide of potassium, and thirteen grammes of corrosive sublimate, in about eight hundred cubic centimetres of distilled water. Add

gradually a cold aqueous saturated solution of corrosive sublimate, until the red color produced just begins to be permanent. Add a hundred and sixty grammes of solid caustic potash to the mixture, which is then to be diluted with sufficient water to bring the whole to a litre. To render the test sensitive, add a little more cold saturated solution of corrosive sublimate, and allow it to settle.

#### DILUTE STANDARD SOLUTION OF AMMONIA.

First prepare a strong solution by dissolving 3.15 grammes of crystallized sal-ammoniac in one litre of distilled water. Bottle and keep on hand.

To prepare the dilute solution: Pour five cubic centimetres of the strong solution into a half-litre flask, and fill it up with distilled water. Mingle very thoroughly by pouring the mixture several times from the flask into the bottle, and from the bottle back again into the flask. This dilute solution contains .01 milligramme in each cubic centimetre.

#### WANKLYN'S SOLUTION.

Dissolve eight grammes of crystallized permanganate of potash, and two hundred grammes

of solid caustic potash in sticks, in one litre of distilled water. Boil the solution until about one-fourth of the amount has passed off as steam, to dissipate all ammonia. Replace the water lost in boiling as steam by adding sufficient distilled water to bring it back to one litre.

#### STANDARD SOLUTION OF SOAP.

Dissolve ten grammes of castile soap in one litre of weak (thirty-five per cent) alcohol. One cubic centimetre of this solution should precipitate one milligramme of carbonate of lime.

#### STANDARD SOLUTION OF LEAD.

Dissolve 1.66 grammes of crystallized acetate of lead in one litre of water. Bottle tight. Each cubic centimetre of the solution contains one milligramme of lead.

#### STANDARD SOLUTION OF COPPER.

Dissolve 3.93 grammes of crystallized sulphate of copper in one litre of water. Each cubic centimetre of solution contains one milligramme of copper.

## STANDARD SOLUTION OF IRON.

Dissolve 4.96 grammes of crystallized proto-sulphate of iron in one litre of water. Each cubic centimetre of solution contains one milligramme of iron.

## STANDARD SOLUTION PERMANGANATE OF POTASH.

Dissolve .395 gramme of permanganate of potash in one litre of distilled water. One cubic centimetre of the solution yields one-tenth of a milligramme of oxygen in presence of acid.

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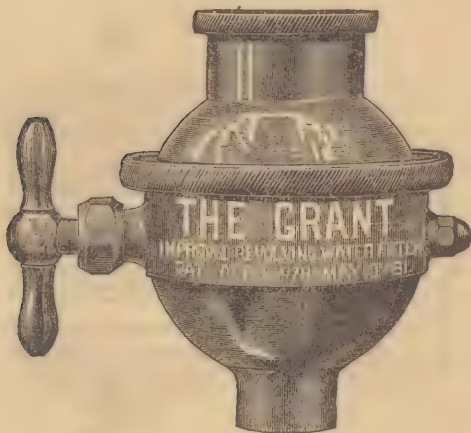
|                                       | Parts per 1,000   |
|---------------------------------------|-------------------|
| Total Solids . . . . .                | 0.1540            |
| Volatile Matter (upon ignition) . . . | 0.0530            |
| Sulphate of Lime . . . . .            | 0.0350            |
| Bi-Carbonate of Lime . . . . .        | 0.0213            |
| Chloride of Magnesium . . . . .       | 0.0342            |
| Chloride of Sodium . . . . .          | 0.0060            |
| Silica (dissolved) . . . . .          | 0.0160            |
| Iron . . . . .                        | Trace.            |
| Nitrates . . . . .                    | Trace.            |
|                                       | Parts per 100,000 |
| Free Ammonia . . . . .                | 0.0053            |
| Albuminoid Ammonia . . . . .          | 0.0070            |

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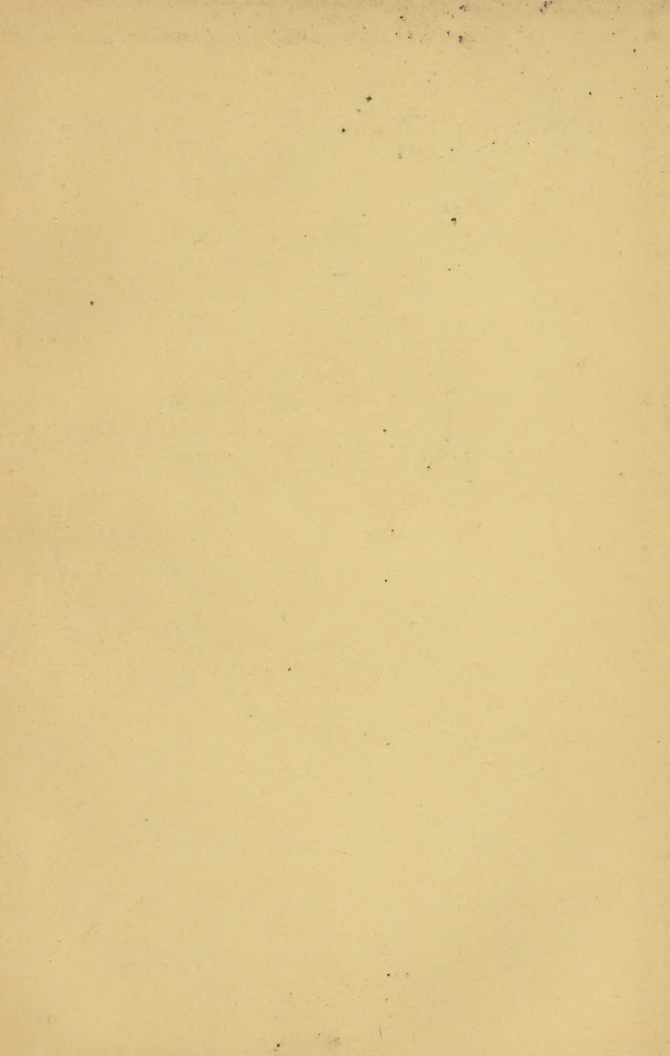


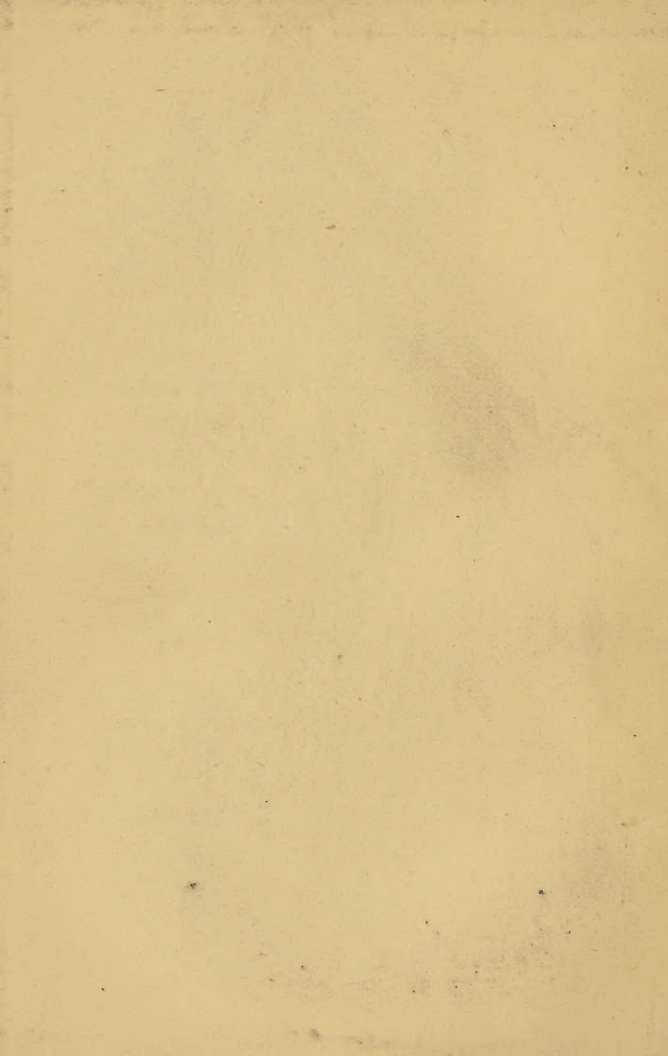


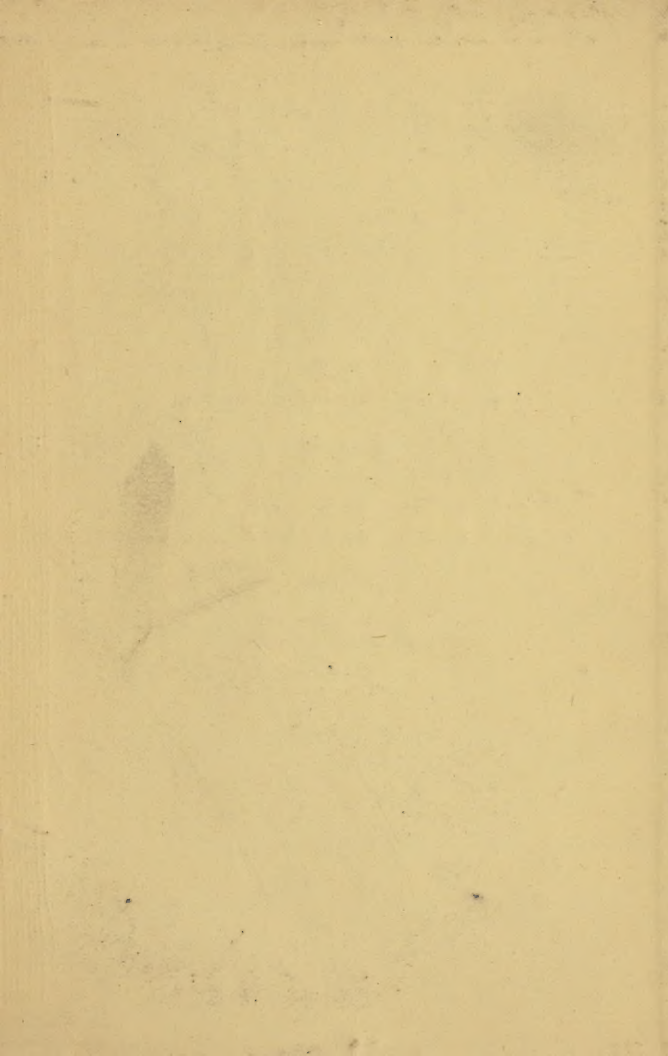














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